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(54) **METHOD OF DISTRIBUTED RECORDING WHEREBY THE NEED TO TRANSITION TO A SECOND RECORDING DEVICE FROM A FIRST RECORDING DEVICE IS BROADCAST BY THE FIRST RECORDING DEVICE**

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(52) **U.S. Cl.** **713/1**; 713/2; 709/231; 711/114; 711/132; 711/170; 710/8

(58) **Field of Classification Search** .... None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,836,722 A 9/1974 Muller et al. .... 179/15 BS

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 383 437 A2 2/1989

(Continued)

OTHER PUBLICATIONS

"*The Parallel Protocol Engine*" Matthias Kaiserswerth, IEEE/ACM Transactions on Networking, Dec. 1993, New York, pp. 650-663.

(Continued)

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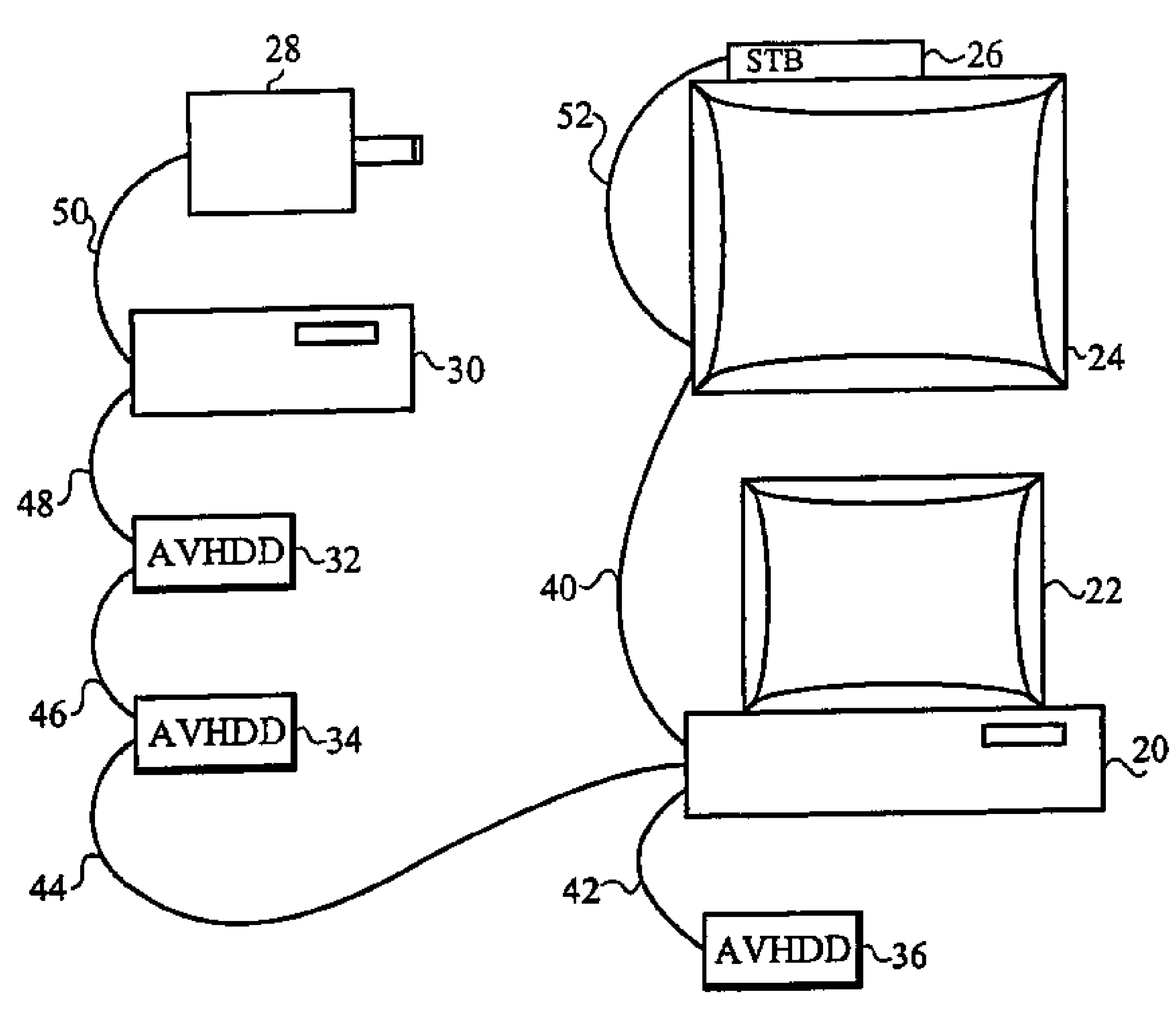
(57) **ABSTRACT**

An automatically configuring storage array includes a plurality of media storage devices coupled together within a network of devices. Preferably, the network of devices is an IEEE 1394-2000 serial bus network of devices. The media storage devices are utilized to record and retrieve streams of data transmitted within the network of devices. The media storage devices communicate with each other in order to store and retrieve streams of data over multiple media storage devices, if necessary. When a record or playback command is received by any one of the media storage devices, the media storage devices send control communications between themselves to ensure that the stream of data is recorded or transmitted, as appropriate. Control of the record or transmit operation is also transferred between the media storage devices in order to utilize the full capacity of the available media storage devices. Preferably, streams of data are recorded utilizing redundancy techniques. An internal file system is included within each media storage device. A file table associated with each recorded stream of data is stored within the internal file system of each media storage device to facilitate search and retrieval of the recorded streams of data throughout the media storage devices. Preferably, the media storage devices accept control instructions directly from devices within the network. Alternatively, a control device is utilized to provide a control interface between the media storage devices and the other devices within the network.

28 Claims, 5 Drawing Sheets



U.S. PATENT DOCUMENTS

3,906,484 A 9/1975 Melvin, Jr. et al. ... 340/347 DD
4,218,756 A 8/1980 Fraser 364/900
4,298,932 A 11/1981 Sams 364/200
4,409,656 A 10/1983 Andersen et al. 364/200
4,410,983 A 10/1983 Cope 371/8
4,493,021 A 1/1985 Agrawal et al. 364/200
4,897,783 A 1/1990 Nay 364/200
4,972,470 A 11/1990 Farago 380/3
4,998,245 A 3/1991 Tanaka et al. 370/85.1
5,007,013 A 4/1991 Elms 364/900
5,008,819 A 4/1991 Gorbatenko 364/200
5,008,879 A 4/1991 Fischer et al. 370/85.2
5,052,029 A 9/1991 James et al. 375/107
5,191,418 A 3/1993 Tran 358/142
5,208,807 A 5/1993 Gass et al. 370/60.1
5,287,478 A 2/1994 Johnston et al. 395/425
5,331,320 A 7/1994 Cideciyan et al. 341/56
5,359,713 A 10/1994 Moran et al. 395/200
5,361,261 A 11/1994 Edem et al. 370/85.3
5,369,773 A 11/1994 Hammerstrom 395/800
5,400,340 A 3/1995 Hillman et al. 370/105.3
5,402,419 A 3/1995 Osakabe et al. 370/85.1
5,412,698 A 5/1995 Van Brunt et al. 375/373
5,420,985 A 5/1995 Cantrell et al. 395/325
5,432,650 A 7/1995 Nunomura et al. 360/27
5,465,402 A 11/1995 Ono et al. 455/161.2
5,473,362 A 12/1995 Fitzgerald et al. 348/7
5,493,570 A 2/1996 Hillman et al. 370/105.3
5,499,344 A 3/1996 Elnashar et al. 395/250
5,506,846 A 4/1996 Edem et al. 370/94.2
5,509,126 A 4/1996 Oprescu et al. 395/307
5,519,701 A 5/1996 Colmant et al. 370/60.1
5,524,213 A 6/1996 Dais et al. 395/200.17
5,526,353 A 6/1996 Henley et al. 370/60.1
5,533,018 A 7/1996 DeJager et al. 370/60.1
5,535,208 A 7/1996 Kawakami et al. 370/84
5,537,408 A 7/1996 Branstad et al. 370/79
5,544,324 A 8/1996 Edem et al. 395/200.17
5,548,587 A 8/1996 Bailey et al. 370/60.1
5,550,802 A 8/1996 Worsley et al. 370/13
5,559,796 A 9/1996 Edem et al. 370/60
5,559,967 A 9/1996 Oprescu et al. 395/285
5,561,427 A 10/1996 Coleman, Jr. 341/161
5,566,174 A 10/1996 Sato et al. 370/84
5,579,278 A 11/1996 McLaury 365/230.05
5,586,264 A 12/1996 Belknap et al. 395/200.08
5,594,732 A 1/1997 Bell et al. 370/401
5,594,734 A 1/1997 Worsley et al. 370/395
5,602,853 A 2/1997 Ben-Michael et al. 370/474
5,603,058 A 2/1997 Belknap et al. 395/855
5,615,382 A 3/1997 Gavin et al. 395/800
5,617,419 A 4/1997 Christensen et al. 370/471
5,619,646 A 4/1997 Hoch et al. 395/200.01
5,632,016 A 5/1997 Hoch et al. 395/200.02
5,640,286 A 6/1997 Acosta et al. 360/48
5,640,392 A 6/1997 Hayashi 370/395
5,640,592 A 6/1997 Rao 370/5
5,646,941 A 7/1997 Nishimura et al. 370/389
5,647,057 A 7/1997 Roden et al. 395/275
5,652,584 A 7/1997 Yoon 341/89
5,655,138 A 8/1997 Kikinis 395/808
5,659,780 A 8/1997 Wu 395/800.19
5,661,848 A 8/1997 Bonke et al. 395/439
5,664,124 A 9/1997 Katz et al. 395/309
5,668,948 A 9/1997 Belknap et al. 395/200.61
5,671,441 A 9/1997 Glassen et al. 395/828
5,684,954 A 11/1997 Kaiserswerth et al. ... 395/200.2
5,687,174 A 11/1997 Edem et al. 370/446
5,687,316 A 11/1997 Graziano et al. 395/200.2
5,689,244 A 11/1997 Iijima et al. 340/825.07
5,689,678 A 11/1997 Stallmo et al. 395/441
5,689,727 A 11/1997 Bonke et al. 395/840
5,691,994 A 11/1997 Acosta et al. 371/40.1
5,692,211 A 11/1997 Gulick et al. 395/800
5,696,924 A 12/1997 Robertson et al. 395/412
5,699,503 A 12/1997 Bolosky et al. 395/182.04
5,704,052 A 12/1997 Wu et al. 395/380
5,706,439 A 1/1998 Parker 395/200.17
5,708,779 A 1/1998 Graziano et al. 395/200.8
5,710,773 A 1/1998 Shiga 370/512
5,752,076 A 5/1998 Munson 395/825
5,758,075 A 5/1998 Graziano et al. 395/200.8
5,761,430 A 6/1998 Gross et al. 395/200.55
5,761,457 A 6/1998 Gulick 395/308
5,764,972 A 6/1998 Crouse et al. 395/601
5,774,683 A 6/1998 Gulick 395/309
5,781,599 A 7/1998 Shiga 375/376
5,781,615 A 7/1998 Bales et al. 379/899
5,787,256 A 7/1998 Marik et al. 395/200.68
5,790,886 A 8/1998 Allen 395/825
5,793,953 A 8/1998 Yeung et al. 395/200.8
5,809,249 A 9/1998 Julyan 395/200.53
5,812,883 A 9/1998 Rao 395/8.94
5,815,678 A 9/1998 Hoffman et al. 395/309
5,828,416 A 10/1998 Ryan 348/512
5,828,903 A 10/1998 Sethuram et al. 395/817
5,835,694 A 11/1998 Hodges 385/182.04
5,835,726 A 11/1998 Shwed et al. 709/229
5,835,793 A 11/1998 Li et al. 395/898
5,848,253 A 12/1998 Walsh et al. 395/309
5,884,103 A 3/1999 Terho et al. 710/22
5,887,145 A 3/1999 Harari et al. 395/282
5,893,148 A 4/1999 Genduso et al. 711/132
5,928,331 A 7/1999 Bushmitch 709/231
5,938,752 A 8/1999 Leung et al. 710/126
5,946,298 A 8/1999 Okuyama 370/232
5,960,036 A 9/1999 Johnson et al. 375/219
5,960,152 A 9/1999 Sawabe et al. 386/98
5,970,236 A 10/1999 Galloway et al. 395/500.44
5,987,126 A 11/1999 Okuyama et al. 380/5
5,991,520 A 11/1999 Smyers et al. 395/280
6,012,117 A 1/2000 Traw et al. 710/123
6,064,676 A 5/2000 Slattery et al. 370/412
6,085,270 A 7/2000 Gulick 710/100
6,145,039 A 11/2000 Ajanovic 710/105
6,233,637 B1 5/2001 Smyers et al. 710/129
6,243,778 B1 6/2001 Fung 710/113
6,247,069 B1 * 6/2001 Smyers 710/8
6,282,597 B1 8/2001 Kawamura 710/105
6,292,844 B1 9/2001 Smyers et al. 710/5
6,334,161 B1 12/2001 Suzuki et al. 710/29
6,374,314 B1 4/2002 Darnell et al. 710/52
6,374,317 B1 4/2002 Ajanovic et al. 710/105
6,438,604 B1 8/2002 Kuver et al. 709/234
6,675,177 B1 1/2004 Webb 707/200
6,859,846 B2 * 2/2005 Swidler et al. 710/8
2005/0259536 A1 * 11/2005 Smyers 369/47.1

FOREIGN PATENT DOCUMENTS

EP	0 428 111	A2	5/1991
EP	0 499 394	A1	8/1992
EP	0 535 434	A2	4/1993
EP	0 588 046	A1	3/1994
EP	0 703 713	A2	1/1996
EP	0 696 853	A2	2/1996
EP	0 789 502	A2	8/1997
EP	0 860 823	A1	8/1998
JP	5-165687		7/1993
JP	411025596	A	1/1999
JP	02000078428	A	3/2000
JP	020000151681	A	5/2000
TW	328997		4/1998
WO	WO 97 33230		9/1997

WO	WO 98 02881	1/1998
WO	WO 98 47271	10/1998

OTHER PUBLICATIONS

"*The Programmable Protocol VLSI Engine* (*PROVE*)" A.S. Krishnakumar, W.C. Fischer, and Krishan Sabnani, IEEE Transactions on Communications, Aug. 1994, New York, pp. 2630-2642.

"*A Bus on a Diet-The Serial Bus Alternative*" Michael Teener, CompCon92, Feb. 24-28, 1992, pp. 316-321.

"*Local Area Network Protocol for Autonomous Control of Attached Devices*" Software Patent Institute, 1995, 1996.

"*Architecture for High Performance Transparent Bridges*" Software Patent Institute, 1995, 1996.

"*Access to High-Speed LAN via Wireless Media*" Software Patent Institute, 1995, 1996.

"*Asynchronous Transfer Mode*" Julia L. Heeter, Dec. 12, 1995.

"*The SerialSoft IEEE 1394 Developer Tool*" Skipstone, pp. 1-158.

"*Data link driver program design for the IBM token ring network PC adapter*" Gee-Swee Poo and Wilson Ang, Computer Communications, 1989, London, Great Britain, pp. 266-272.

"*Fiber Channel* (*FCS*)/*ATM interworking: A design solution*" A. Anzaloni, M. De Sanctis, F. Avaltroni, G. Rulli, L. Proietti and G. Lombardi, Ericsson Fatme R&D Division, Nov. 1993, pp. 1127-1133.

"*Data Exchange Adapter for Micro Channel/370*" Software Patent Institute, 1995, 1996.

American National Standards Institute X3T10 Technical Committee, *Information Technology—Serial Bus Protocol 2* (*SBP-2*)Project 1155D, Revision le, Nov. 9, 1996.

IEEE, "*1394 Standard for a High Performance Serial Bus*" 1995, USA.

"*IEEE 1394, The Cable Connection to Complete the Digital Revolution*" Daniel Moore.

"*1394 200 Mb/ s PHYsical Layer Transceiver*" IBM Microelectronics, Product Data Sheet and Application Notes, Version 1.4, Mar. 14, 1996.

"*IEEE 1394-1995 Triple Cable Transceiver/ Arbiter,*" Texas Instruments TSB21LV03, Product Preview, Revision0.99, Mar. 19, 1996.

"*The IEEE-1349 High Speed Serial Bus*" R.H.J. Bloks, Phillips Journal of Research, vol. 50, pp. 209-216, Jul. 1996.

Hoffman, et al., "*IEEE 1394: A Ubiquitous Bus,*" Digest of Papers of the Computer Socity, Computer Conference (COMPCON) Technologies for the Information Superhighway, Mar. 5, 1999 pp. 334-338.

* cited by examiner

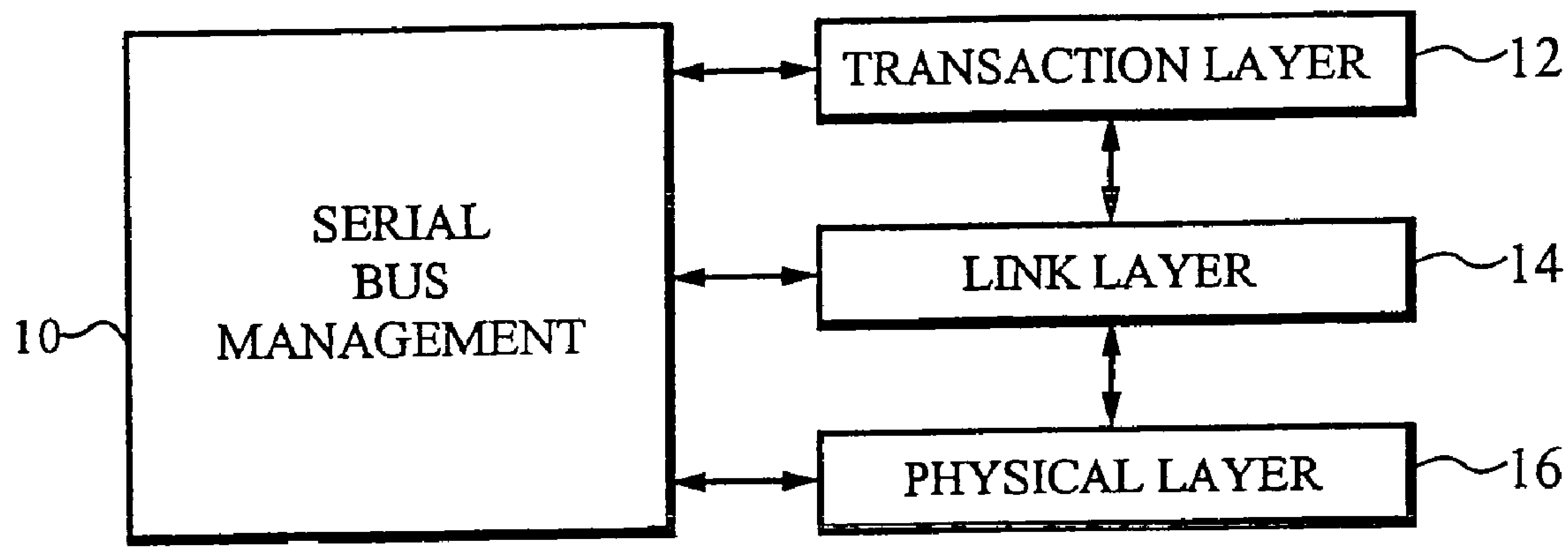
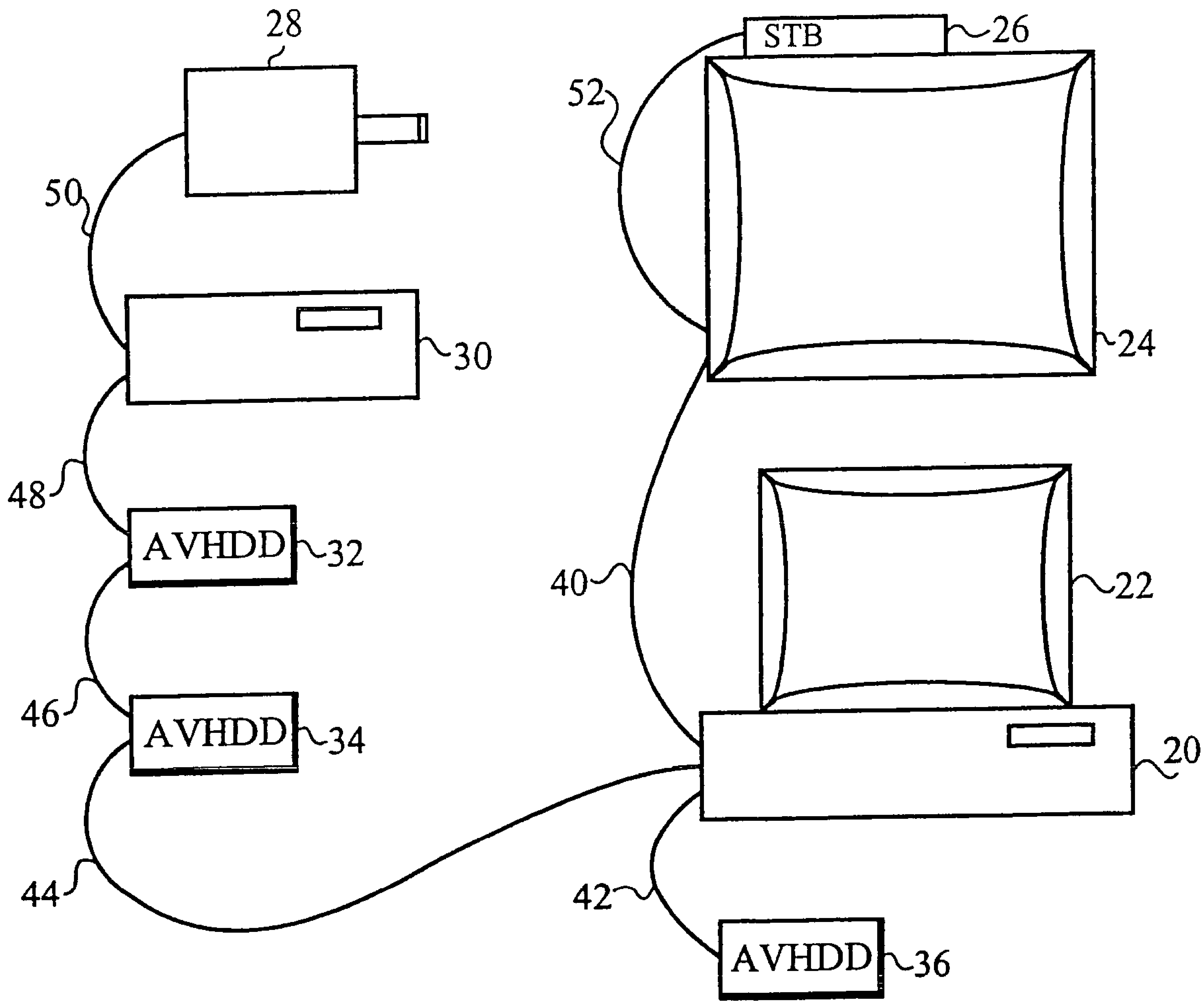


Fig. 1 (PRIOR ART)


28
STB
26
52
50
30
24
48
AVHDD
32
22
40
46
AVHDD
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44
42
AVHDD
36

Fig. 2

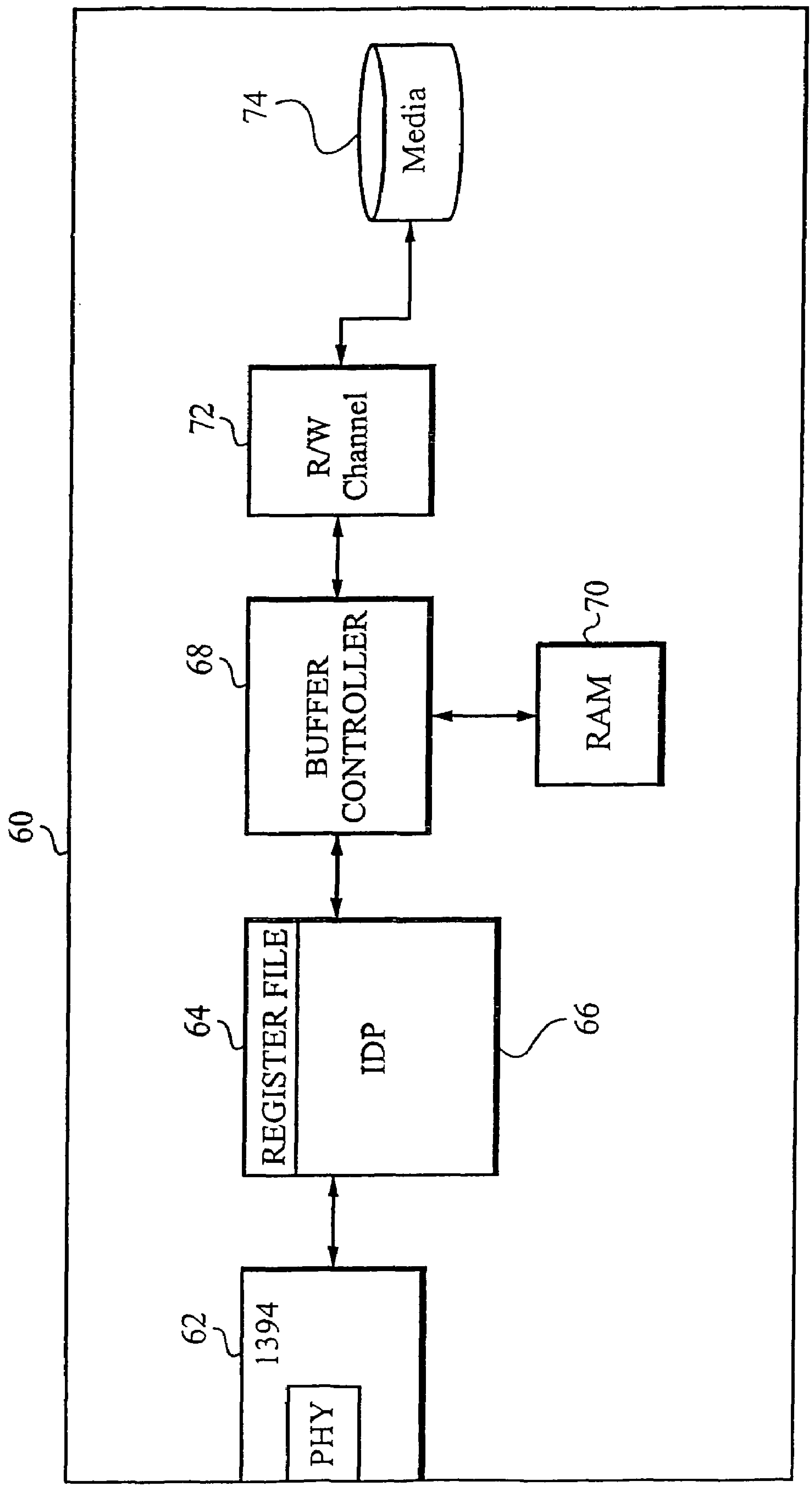
60
62
1394
PHY
64
REGISTER FILE
IDP
66
68
BUFFER CONTROLLER
70
RAM
72
R/W Channel
74
Media

Fig. 3

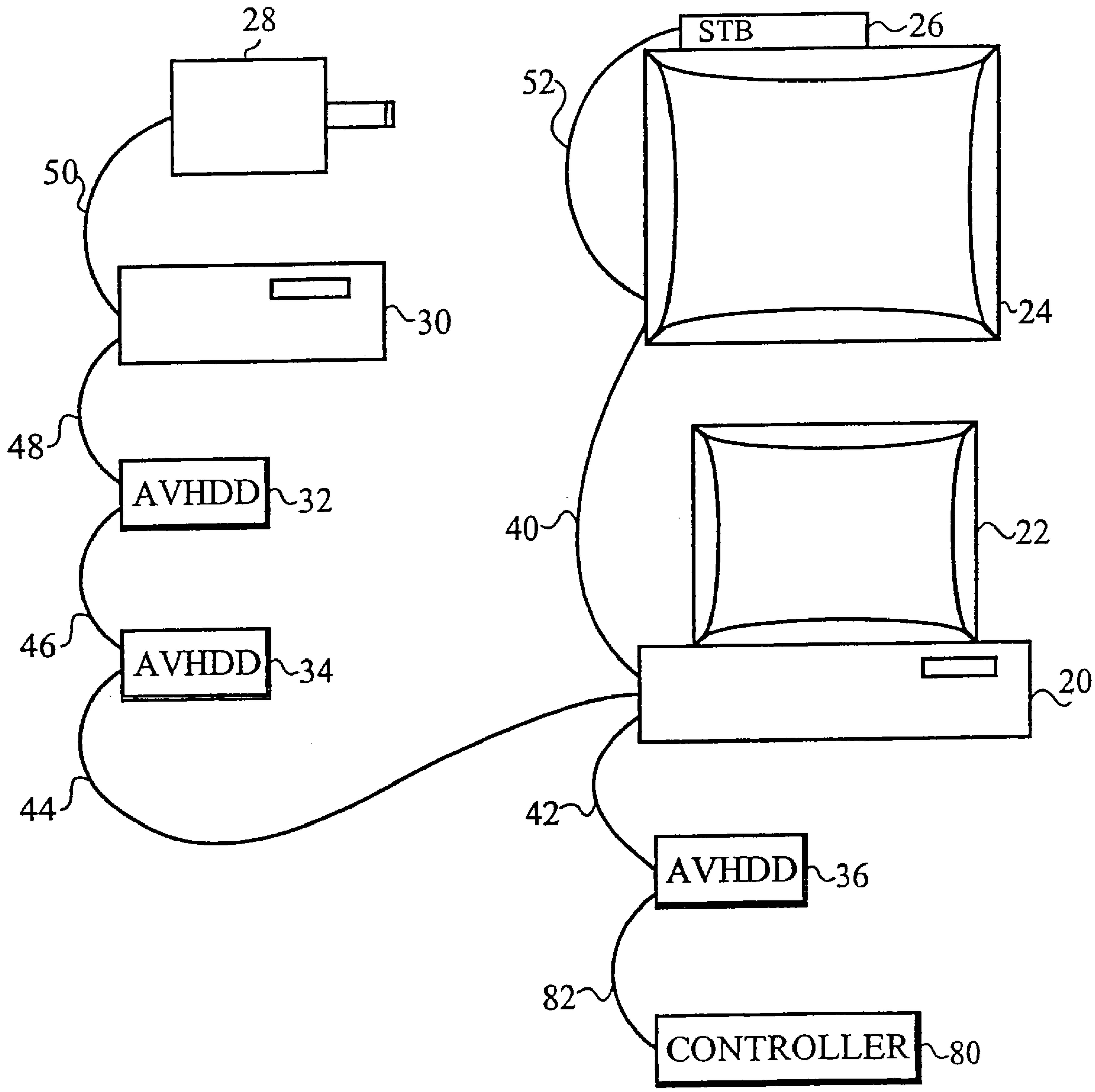
28
STB
26
52
50
30
24
48
AVHDD
32
22
40
46
AVHDD
34
20
44
42
AVHDD
36
82
CONTROLLER
80

Fig. 4

100

102	104	106	108	110	112	
Time (H)	Time (M)	Time (S)	Time (F)	Data-Type	Data	
0	0	0	1	LBA	0	114
•	•	•	•	•	•	
•	•	•	•	•	•	
•	•	•	•	•	•	
1	20	12	6	LBA	12345	116
•	•	•	•	•	•	
•	•	•	•	•	•	
2	25	15	1	LBA	23456	118
2	25	15	2	DEVICE	GUID B	120

Fig. 5

200

202	204	206	208	210	212	
Time (H)	Time (M)	Time (S)	Time (F)	Data-Type	Data	
2	25	15	1	DEVICE	GUID A	214
2	25	15	2	LBA	123	216
•	•	•	•	•	•	

Fig. 6

METHOD OF DISTRIBUTED RECORDING WHEREBY THE NEED TO TRANSITION TO A SECOND RECORDING DEVICE FROM A FIRST RECORDING DEVICE IS BROADCAST BY THE FIRST RECORDING DEVICE

RELATED APPLICATIONS

This Patent Application is a continuation of U.S. patent application Ser. No. 10/210,928, filed on Aug. 2, 2002 now U.S. Pat. No. 6,859,846 and entitled A METHOD OF DISTRIBUTED RECORDING WHEREBY THE NEED TO TRANSITION TO A SECOND RECORDING DEVICE FROM A FIRST RECORDING DEVICE IS BROADCAST BY THE FIRST RECORDING DEVICE, which is a continuation-in-part of U.S. patent application Ser. No. 09/861,825, filed on May 21, 2001 and entitled AUTOMATICALLY CONFIGURING STORAGE ARRAY INCLUDING A PLURALITY OF MEDIA STORAGE DEVICES FOR STORING AND PROVIDING DATA WITHIN A NETWORK OF DEVICES, which is a continuation of application Ser. No. 09/310,876, filed May 12, 1999, now issued U.S. Pat. No. 6,247,069, issued on Jun. 12, 2001 and entitled AUTOMATICALLY CONFIGURING STORAGE ARRAY INCLUDING A PLURALITY OF MEDIA STORAGE DEVICES FOR STORING AND PROVIDING DATA WITHIN A NETWORK OF DEVICES. The U.S. patent application Ser. No. 10/210,928, filed on Aug. 2, 2002 and entitled A METHOD OF DISTRIBUTED RECORDING WHEREBY THE NEED TO TRANSITION TO A SECOND RECORDING DEVICE FROM A FIRST RECORDING DEVICE IS BROADCAST BY THE FIRST RECORDING DEVICE, the U.S. patent application Ser. No. 09/861,825, filed on May 21, 2001 and entitled AUTOMATICALLY CONFIGURING STORAGE ARRAY INCLUDING A PLURALITY OF MEDIA STORAGE DEVICES FOR STORING AND PROVIDING DATA WITHIN A NETWORK OF DEVICES and issued U.S. Pat. No. 6,247,069, issued on Jun. 12, 2001 and entitled AUTOMATICALLY CONFIGURING STORAGE ARRAY INCLUDING A PLURALITY OF MEDIA STORAGE DEVICES FOR STORING AND PROVIDING DATA WITHIN A NETWORK OF DEVICES are also hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to the field of writing data to and reading data from media storage devices. More particularly, the present invention relates to the field of writing data to and reading data from media storage devices within a network of devices.

BACKGROUND OF THE INVENTION

The IEEE 1394-2000 standard, "1394 Standard For A High Performance Serial Bus," is an international standard for implementing an inexpensive high-speed serial bus architecture which supports both asynchronous and isochronous format data transfers. In addition, the IEEE 1394-2000 bus has a universal clock called the cycle timer. This clock is synchronized on all nodes. Isochronous data transfers are real-time transfers which take place based on the universal clock such that the time intervals between significant instances have the same duration at both the transmitting and receiving applications. Each packet of data transferred isochronously is transferred in its own time period. An example of an ideal application for the transfer of data isochronously would be from a video recorder to a television set. The video recorder records images and sounds and saves the data in discrete chunks or packets. The video recorder then transfers each packet, representing the image and sound recorded over a limited time period, during that time period, for display by the television set. The IEEE 1394-2000 standard bus architecture provides multiple independent channels for isochronous data transfer between applications. A six bit channel number is broadcast with the data to ensure reception by the appropriate application. This allows multiple applications to simultaneously transmit isochronous data across the bus structure. Asynchronous transfers are traditional reliable data transfer operations which take place as soon as arbitration is won and transfer a maximum amount of data from a source to a destination.

The IEEE 1394-2000 standard provides a high-speed serial bus for interconnecting digital devices thereby providing a universal I/O connection. The IEEE 1394-2000 standard defines a digital interface for the application thereby eliminating the need for an application to convert digital data to analog data before it is transmitted across the bus. Correspondingly, a receiving application will receive digital data from the bus, not analog data, and will therefore not be required to convert analog data to digital data. The cable required by the IEEE 1394-2000 standard is very thin in size compared to other bulkier cables used to connect such devices in other connection schemes. Devices can be added and removed from an IEEE 1394-2000 bus while the bus is operational. If a device is so added or removed the bus will then automatically reconfigure itself for transmitting data between the then existing nodes. A node is considered a logical entity with a unique address on the bus structure. Each node provides in a standard address space, an identification ROM, a standardized set of control registers and in addition, its own address space.

The IEEE 1394-2000 standard defines a protocol as illustrated in FIG. **1**. This protocol includes a serial bus management block **10** coupled to a transaction layer **12**, a link layer **14** and a physical layer **16**. The physical layer **16** provides the electrical and mechanical connection between a device and the IEEE 1394-2000 cable. The physical layer **16** also provides arbitration to ensure that all devices coupled to the IEEE 1394-2000 bus have arbitrated access to the bus as well as actual data transmission and reception. The link layer **14** provides data packet delivery service for both asynchronous and isochronous data packet transport. This supports both asynchronous data transport, using an acknowledgment protocol, and isochronous data transport, providing an un-acknowledged real-time guaranteed bandwidth protocol for just-in-time data delivery. The transaction layer **12** supports the commands necessary to complete asynchronous data transfers, including read, write and lock. The serial bus management block **10** contains an isochronous resource manager for managing the resources associated with isochronous data transfers. The serial bus management block **10** also provides overall configuration control of the serial bus in the form of optimizing arbitration timing, guarantee of adequate electrical power for all devices on the bus, assignment of the cycle master, assignment of isochronous channel and bandwidth resources and basic notification of errors.

The AV/C Command Set is a command set used for transactions to and from consumer audio/video equipment over an IEEE 1394-2000 serial bus. This AV/C command set makes use of the Function Control Protocol (FCP) defined by IEC-61883, the ratified international standard for the transport of audio/video command requests and responses. AV/C commands are transmitted through AV/C transactions. An AV/C transaction consists of one AV/C command frame addressed to the target node's FCP_Command register and zero or more AV/C response frames addressed to the requesting node's FCP_Response register.

Each audio/video unit or subunit can implement a subset of the AV/C command set. An unsupported command received by an audio/video unit is rejected with a not implemented response. Support for the different commands is characterized as mandatory, recommended, optional and vendor-dependent. A mandatory command is supported by any audio/video device that claims compliance with the AV/C command set and that implements the audio/video unit or subunit type for which the command is defined. An AV/C compliant device is identified by an entry within its configuration read-only memory (ROM). A recommended command is optional for an AV/C compliant device, but represents a basic functionality, such as video and audio insert modes for a VCR subunit's record command. If the device supports a unit or subunit type that has the functionality corresponding to the command, it is recommended that the command be implemented. An optional command is optional for an AV/C compliant device. Support for and interpretation of a vendor-dependent command are defined by the device vendor.

AV/C commands are grouped into four command types including control, status, inquiry and notify command types. A control command is sent by a controller to another audio/video device, the target, to instruct the target to perform an operation. A target that receives a control command will return an AV/C response frame including either a not implemented, accepted, rejected or interim response code. The target will return a not implemented response code when the target does not support the control command specified or the command is addressed to a subunit not implemented by the target. The target will return an accepted response code when the target implements the control command specified and the current state of the target permits execution of the command. The target will return a rejected response code when the target implements the control command specified but the current state of the target does not permit execution of the command. The target will return an interim response code if the control command specified is implemented by the target, but the target is unable to respond with either an accepted or rejected response code within 100 milliseconds. Unless a subsequent bus reset causes the AV/C transaction to be aborted, the target will ultimately return a response frame with an accepted or rejected response code after returning an interim response code.

A status command is sent by a controller to an audio/video device to request the current status of the target device. Status commands may be sent to either audio/video units or subunits. A target that receives a status command will return an AV/C response frame including either a not implemented, rejected, in transition or stable response code. A target will return a not implemented status response code when the target does not support the status command specified or the command is addressed to a subunit not implemented by the target. A target will return a rejected status response code when the target implements the status command specified but the target state does not permit the return of status for the command. The target will return an in transition status response code when the target implements the status command specified, but the current state of the target is in transition. The target will return a stable status response code when the target implements the status command specified and the information requested is reported in the values in the AV/C response frame.

An inquiry command is used by a controller to determine whether or not a target audio/video device supports a particular control command. A controller can reliably use inquiry commands to probe the capabilities of a target, since the target shall not modify any state nor initiate any command execution in response to an inquiry command. A target that receives an inquiry command will return an AV/C response frame including either an implemented or a not implemented response code. An implemented response code notifies the controlling node that the corresponding control command specified is implemented by the target audio/video device. A not implemented response code notifies the controlling node that the corresponding control command specified is implemented by the target audio/video device.

A notify command is used by a controller to receive notification of future changes in an audio/video device's state. Responses to a notify command will indicate the current state of the target and then, at some indeterminate time in the future, indicate the changed state of the target. A target that receives a notify command will return an immediate response frame including either a not implemented, rejected or interim response code. A target will return a not implemented response code when the target does not support the notify command specified or the command is addressed to a subunit not implemented by the target. A target will return a rejected response code when the target implements event notification for the condition specified but is not able to supply the requested information. A target will return an interim response code when the target supports the requested event notification and has accepted the notify command for any future change of state. The current state is indicated by the data returned in the response frame. At a future time, the target will then return an AV/C response frame with either a rejected or changed response code.

A traditional hard disk drive records data and plays it back according to commands received from an external controller using a protocol such as the serial bus protocol (SBP). The external controller provides command data structures to the hard disk drive which inform the hard disk drive where on the media the data is to be written, in the case of a write application, or read from, in the case of a read operation.

Use of a media storage device, such as a hard disk drive, for storing streams of audio and video data is taught in U.S. patent application Ser. No. 09/022,926, filed on Feb. 12, 1998 and entitled "MEDIA STORAGE DEVICE WITH EMBEDDED DATA FILTER FOR DYNAMICALLY PROCESSING DATA DURING READ AND WRITE OPERATIONS," which is hereby incorporated by reference. When storing audio and video data streams on such a hard disk drive, the available capacity of the device can be quickly utilized, due to the large amounts of data included in typical audio and video data streams. If multiple traditional hard disk drives are utilized to store large streams of data, then the user must typically be responsible for management of these storage and retrieval procedures. This storage management responsibility adds complexity to operations such as record and playback and requires the user to monitor and control storage and retrieval operations.

SUMMARY OF THE INVENTION

An automatically configuring storage array includes a plurality of media storage devices coupled together within a network of devices. Preferably, the network of devices is an

IEEE 1394-2000 serial bus network of devices. The media storage devices are utilized to record and retrieve streams of data transmitted within the network of devices. The media storage devices communicate with each other in order to store and retrieve streams of data over multiple media storage devices, if necessary. When a record or playback command is received by any one of the media storage devices, the media storage devices send control communications between themselves to ensure that the stream of data is recorded or transmitted, as appropriate. Control of the record or transmit operation is also transferred between the media storage devices in order to utilize the full capacity of the available media-storage devices. Preferably, streams of data are recorded utilizing redundancy techniques. An internal file system is included within each media storage device. A file table associated with each recorded stream of data is stored within the internal file system of each media storage device to facilitate search and retrieval of the recorded streams of data throughout the media storage devices. Preferably, the media storage devices accept control instructions directly from devices within the network. Alternatively, a control device is utilized to provide a control interface between the media storage devices and the other devices within the network.

In one aspect of the present invention, a method of recording data within an automatically configuring storage array including a plurality of media storage devices includes receiving a record command to record a stream of data at one of the media storage devices, determining a next available media storage device independent of the record command, recording the stream of data on media within the next available media storage device, thereby forming a recorded stream of data, recording a file table associated with the recorded stream of data within the next available media storage device, wherein the file table includes identifying and pointing information about the recorded stream of data, sending control communications from the next available media storage device to other media storage devices within the automatically configuring storage array, and repeating the above process when the next available media storage device does not have capacity to record remaining portions of the stream of data, until the stream of data is fully recorded. Control communications are sent to identify the next available media storage device when recording responsibility is transferred from a current recording media storage device to the next available media storage device. The control communications and the stream of data are sent over a serial bus that substantially complies with an IEEE 1394 standard. Each media storage device that stores a portion of the recorded stream of data includes the file table associated with the portion of the recorded stream of data stored on that media storage device. The identifying and pointing information within the file table includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data. Determining the next available media storage device is performed by sending a broadcast message to the plurality of media storage devices requesting response from each media storage device that has available storage capacity and selecting the next available media storage device from those media storage devices that respond to the broadcast message. The next available media storage device is selected from the media storage devices that respond to the broadcast message based on the media storage device that has the most available storage capacity. The next available media storage device is selected from the media storage devices that respond to the broadcast message based on the media storage device that is a first to respond to the broadcast message. The record command is received from a remote controller. The stream of data is transmitted on a data isochronous channel. The control communications include a real time component transmitted on a control isochronous channel. The control communications include a non-real time component transmitted by asynchronous commands. The method further includes recording redundant information regarding the stream of data which is used to reconstruct lost data within the recorded stream of data. Each frame within the recorded stream of data is identified by the elapsed time from the start of the recorded stream of data to the frame, wherein the elapsed time is measured in hours, minutes, seconds and frames.

In another aspect of the present invention, a method of recording data within an automatically configuring storage array including a plurality of media storage devices includes receiving a record command to record a stream of data at one of the media storage devices, determining a next available media storage device independent of the record command, recording the stream of data on media within the next available media storage device, thereby forming a recorded stream of data, recording a file table associated with the recorded stream of data within the next available media storage device, wherein the file table is stored on and maintained by the next available media storage device and includes identifying and pointing information about the recorded stream of data, sending control communications from the next available media storage device to other media storage devices within the automatically configuring storage array, and repeating the above process when the next available media storage device does not have capacity to record remaining portions of the stream of data, until the stream of data is fully recorded, wherein each media storage device that stores a portion of the recorded stream of data includes the file table associated with the portion of the recorded stream of data stored on that media storage device. Control communications are sent to identify the next available media storage device when recording responsibility is transferred from a current recording media storage device to the next available media storage device The control communications and the stream of data are sent over a serial bus that substantially complies with an IEEE 1394 standard. The identifying and pointing information within the file table includes a correlation between each frame within the portion of the recorded stream of data and that frames' storage location within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data. Determining the next available media storage device is performed by sending a broadcast message to the plurality of media storage devices requesting response from each media storage device that has available storage capacity and selecting the next available media storage device from those media storage devices that respond to the broadcast message. The next available media storage device is selected from the media storage devices that respond to the broadcast message based on the media storage device that has the most available storage capacity. The next available media storage device is selected from the media storage devices that respond to the broadcast message based on the media storage device that is a first to respond to the broadcast message.

In yet another aspect of the present invention, an automatically configuring storage array within a network of devices including data source devices and data reception devices, the automatically configuring storage array including a plurality of distributed intelligent media storage devices having ability to automatically configure themselves and record a received stream of data over multiple media storage devices, thereby forming a recorded stream of data, wherein each media storage device that stores a portion of the recorded stream of data includes a file table associated with the portion of the recorded stream of data for identifying and pointing to portions of the recorded stream of data stored on different media storage devices. The file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data. The recorded stream of data is recorded utilizing redundancy recording techniques. The automatically configuring storage array can further include a controller coupled to the media storage devices to initiate record and transmit operations. The media storage devices include one or more hard disk drives. The automatically configuring storage array is formed within a serial bus network of devices that substantially complies with an IEEE 1394 standard.

In still yet another aspect of the present invention, an automatically configuring storage array within a network of devices including data source devices and data reception devices, the automatically configuring storage array including a plurality of distributed intelligent media storage devices having ability to automatically configure themselves and record a received stream of data over multiple media storage devices, thereby forming a recorded stream of data, and to automatically retrieve and playback the recorded stream of data, wherein each media storage device that stores a portion of the recorded stream of data includes a file table associated with the portion of the recorded stream of data for identifying and pointing to portions of the recorded stream of data stored on different media storage devices. The file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data. The recorded stream of data is recorded utilizing redundancy recording techniques. The automatically configuring storage array can further include a controller coupled to the media storage devices to initiate record, playback and transmit operations. The media storage devices include one or more hard disk drives. The automatically configuring storage array is formed within a serial bus network of devices that substantially complies with an IEEE 1394 standard.

In other aspect of the present invention, a method of recording data within an automatically configuring storage array including a plurality of media storage devices includes receiving a record command to record a stream of data at one of the media storage devices, determining a next available media storage device independent of the record command by sending a broadcast message to the plurality of media storage devices requesting response from each media storage device that has available storage capacity and selecting the next available media storage device from those media storage devices that respond to the broadcast message, recording the stream of data on media within the next available media storage device, thereby forming a recorded stream of data, recording a file table associated with the recorded stream of data within the next available media storage device, wherein the file table includes identifying and pointing information about the recorded stream of data, sending control communications from the next available media storage device to other media storage devices within the automatically configuring storage array, and repeating the above process when the next available media storage device does not have capacity to record remaining portions of the stream of data, until the stream of data is fully recorded. The next available media storage device is selected from the media storage devices that respond to the broadcast message based on the media storage device that has the most available storage capacity. The next available media storage device is selected from the media storage devices that respond to the broadcast message based on the media storage device that is a first to respond to the broadcast message.

In a further aspect of the present invention, a network of devices includes a source device for providing a stream of data, and an automatically configuring storage array coupled to the source device, the automatically configuring storage array including a plurality of distributed intelligent media storage devices having ability to automatically configure themselves and record the received stream of data over multiple media storage devices, thereby forming a recorded stream of data, wherein each media storage device that stores a portion of the recorded stream of data includes a file table associated with the portion of the recorded stream of data for identifying and pointing to portions of the recorded stream of data stored on different media storage devices. The file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data. The recorded stream of data is recorded utilizing redundancy recording techniques. The network of devices can further include a controller coupled to the media storage devices to initiate record and transmit operations. The media storage devices include one or more hard disk drives. The network of devices is formed by a serial bus network of devices that substantially complies with an IEEE 1394 standard.

In another aspect of the present invention, a distributed file table representing storage locations corresponding to a recorded stream of data, the distributed file table including one or more file tables, wherein each file table is associated with a portion of the recorded stream of data stored on one of a plurality of distributed intelligent media storage devices within a network of devices and includes identifying information about the portion of the recorded stream of data on the media storage device and pointing information about other portions of the recorded stream of data on different media storage devices, further wherein each file table is maintained by and recorded onto the media storage device on which the associated portion of the recorded stream of data is recorded. Each file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data. The distributed file table can further include a controller coupled to the media storage device to maintain and record the information included within the file table corresponding to the media storage device.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a protocol defined by the IEEE 1394-2000 standard.

FIG. **2** illustrates an exemplary IEEE 1394-2000 serial bus network of devices including a video camera, a video cassette recorder, a settop box, a television, a computer and audio/video hard disk drives of the present invention.

FIG. **3** illustrates a block diagram of a media storage device according to the preferred embodiment of the present invention.

FIG. **4** illustrates an exemplary IEEE 1394-2000 serial bus network of devices including a separate dedicated storage array controller.

FIG. **5** illustrates an exemplary file table corresponding to a first portion of an audio/video (AV) file A recorded onto a first media storage device.

FIG. **6** illustrates a file table corresponding to a second portion of the AV file A recorded onto a second media storage device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Preferred Embodiment

File Tables

In a network of devices, including a plurality of media storage devices, the media storage devices operate together to form an automatically configuring storage array for storing and providing streams of data, such as audio and video data. The operation of the automatically configuring storage array of media storage devices is seamless and transparent to the user and to other devices within the network. When a record command is sent to any one of the media storage devices within the automatically configuring storage array, that media storage device will then determine the appropriate media storage device to begin recording the stream of data. The record command is forwarded to that device which will then begin recording the stream of data. When the capacity within the current recording media storage device is filled, the current recording media storage device will broadcast a request over the network for any other media storage device with available recording space to respond. The current recording media storage device will then choose one of the responding media storage devices, herein referred to as a next available media storage device, and then notify the next available media storage device of a time at which the next available media storage device is to begin recording the stream of data. This process continues until the entire stream of data is recorded and the source device ceases transmitting.

The stream of data is preferably transmitted from a source device on an isochronous channel over an IEEE 1394-2000 serial bus. Communications between the media storage devices are preferably sent on a separate isochronous communications channel over the IEEE 1394-2000 serial bus. Preferably, each of the media storage devices include an isochronous data pipe which controls data storage and retrieval operations, thereby transferring control and communications between the available media storage devices. Preferably, the media storage devices accept control instructions directly from other devices within the network. Alternatively, a separate control device within the network is utilized to provide a control interface between the media storage devices and the other devices within the network. Preferably, the media storage devices are hard disk drives. Alternatively, any appropriate available media storage device can be utilized within the automatically configuring array of devices.

When recording a stream of data, each of the recording media storage devices preferably uses a file system to facilitate subsequent retrieval and playback of the recorded stream of data. Utilizing this file system, when recording starts at a media storage device, an indexed file table is generated that tracks the storage location of the recorded stream of data on the media storage device. The file table correlates each frame to its location on the media storage device. Each frame is measured in hours, minutes, seconds, and frames from the start of the stream of data. This file table is stored on the media storage device and associated with the stream of data. The file table also includes information regarding where an earlier portion of the stream of data is recorded, if appropriate, and where a subsequent portion of the stream of data is recorded, if appropriate. When recording of the stream of data is transferred to the next available media storage device, a file table is generated by the next available media storage device and associated with the portion of the stream of data recorded on the next available media storage device. In this manner, each media storage device that includes a recorded portion of the stream of data also includes an associated file table for the recorded portion of the stream of data. Using these file tables, a search forward and backward through the recorded stream of data can be accomplished to find a specific location within the recorded stream of data. The file tables are also utilized during retrieval of the recorded stream of data to transfer control of the playback operation to the appropriate media storage devices which were used to record the stream of data.

Preferably, when recording a stream of data from a source device, redundancy techniques are utilized to ensure the integrity of the recorded stream of data. This redundancy is used to prevent the loss of data or facilitate the reconstruction of lost data if one of the media storage devices within the automatically configuring storage array is removed from the network of devices. If a media storage device is removed, then the remaining media storage devices will preferably automatically recreate the data that was stored on the removed media storage device.

FIG. **2** illustrates an exemplary network of devices including a video camera **28**, a video cassette recorder (VCR) **30**, a settop box **26**, a television **24**, a computer **20** and audio/video hard disk drives (AVHDD) **32**, **34** and **36** connected together by IEEE 1394-2000 cables **40**, **42**, **44**, **46**,**48**, **50** and **52**. The IEEE 1394-2000 cable **50** couples the video camera **28** to the VCR **30**, allowing the video camera **28** to send data, commands and parameters to the VCR **30** for recording. The IEEE 1394-2000 cable **48** couples the VCR **30** to the AVHDD **32**. The IEEE 1394-2000 cable **46** couples the AVHDD **32** to the AVHDD **34**. The IEEE 1394-2000 cable **44** couples the AVHDD **34** to the computer **20**. The IEEE 1394-2000 cable **42** couples the computer **20** to the AVHDD **36**. The IEEE 1394-2000 cable **40** couples the computer **20** to the television **24**. The IEEE 1394-2000 cable **52** couples the television **24** to the settop box **26**.

The configuration illustrated in FIG. **2** is exemplary only. It should be apparent that an audio/video network could include many different combinations of components. The devices within such an IEEE 1394-2000 network are autonomous devices, meaning that in an IEEE 1394-2000 network, as the one illustrated in FIG. **2**, in which a computer is one of the devices, there is not a true "master-slave" relationship between the computer and the other devices. In many IEEE 1394-2000 network configurations, a computer may not be present. Even in such configurations, the devices within the network are fully capable of interacting with each other on a peer basis. It should be recognized that data, commands and parameters can be sent between all of the devices within the IEEE 1394-2000 network, as appropriate.

A block diagram of a hardware system resident in each AVHDD of the preferred embodiment of the present invention is illustrated in FIG. **3**. The AVHDD **60** preferably includes an IEEE 1394-2000 serial bus interface circuit **62** for sending communications to and receiving communications from other devices coupled to the IEEE 1394-2000 serial bus network. The interface circuit **62** is coupled to an isochronous data pipe **66**. The isochronous data pipe **66** includes a register file **64**. The isochronous data pipe **66** is coupled to a buffer controller **68**. The buffer controller **68** is also coupled to a random access memory circuit **70** and to a read/write channel circuit **72**. The read/write channel circuit **72** is coupled to media **74** on which data is stored within the AVHDD **60**. The read/write channel circuit **72** controls the storage operations on the media **74**, including reading data from the media **74** and writing data to the media **74**.

Each of the AVHDDs **32**, **34** and **36** follow protocols which are described herein and allow each of the AVHDDs **32**, **34** and **36** to coordinate activities with each of the other AVHDDs so that the operation of the AVHDDs appears to a user and other components as a single media storage device. In the preferred embodiment of the present invention, the isochronous data pipe **66** within each of the AVHDDs **32**, **34** and **36** in the network of devices control the storage operations of writing data to and reading data from the AVHDDs **32**, **34** and **36**. Alternatively, a separate controlling device is utilized to monitor and control the activities of the AVHDDs **32**, **34** and **36**. This controller can either be a device within the network, such as the computer **20** or the settop box **26**, or a separate dedicated controller **80**, as illustrated in FIG. **4**.

In the embodiment illustrated in FIG. **4**, the controller **80** is coupled to the AVHDD **36** by the IEEE 1394-2000 cable **82**. The controller **80** includes an appropriate user interface which enables a user to interact with the controller **80** and through the controller **80** control the interconnected components within the automatically configuring storage array. The controller **80** includes the ability to recognize and control the AVHDDs **32**, **34** and **36**, as well as sources of audio/video data such as the video camera **28**, the VCR **30**, the television **24**, the settop box **26** and the computer system **20**.

In the embodiment illustrated in FIG. **4**, when the controller **80** receives an instruction to record an audio/video stream of data, the controller **80** initiates the recording process utilizing the AVHDDs **32**, **34** and **36** available within the network of devices. After receiving an instruction to record an audio/video stream of data, the controller **80** locates the source of the data stream to be recorded, such as the settop box **26**, and instructs it to begin transmitting the stream of data to be recorded on the IEEE 1394-2000 serial bus. The controller **80** obtains self describing information embedded within the source device over the IEEE 1394-2000 serial bus. The controller **80** utilizes the self describing information to locate the source device and learn how to control the source device. The controller **80** then utilizes the AV/C command set, appropriate for the source device, to control the source device. The stream of data is transmitted in a digital format over an isochronous channel on the IEEE 1394-2000 serial bus.

After receiving an instruction to record an audio/video stream of data, the controller **80** also locates one of the AVHDDs **32**, **34** and **36** within the network, and instructs the selected one of the AVHDDs **32**, **34** and **36** to begin recording the stream of data coming from the source device. The controller **80** obtains self describing information embedded within the selected AVHDD over the IEEE 1394-2000 serial bus. The controller **80** utilizes the self describing information to locate the selected AVHDD and learn how to control the selected AVHDD. In this embodiment, it does not matter which one of the AVHDDs **32**, **34** and **36**, the controller **80** selects and instructs to record.

When the selected AVHDD receives the record instruction from the controller **80**, the selected AVHDD first determines if it has available storage capacity, and if so, the selected AVHDD accepts the record command. If the selected AVHDD determines that it does not have available storage capacity, then the selected AVHDD determines which one of the other AVHDDs within the network should record the next stream of data. This determination is based on the available capacity of each of the other AVHDDs and the current responsibilities of those AVHDDs. Once the selected AVHDD determines which one of the other AVHDDs will record this stream of data, the selected AVHDD forwards the record command to that other AVHDD, which will be referred to herein as the recording AVHDD. If the selected AVHDD is not able to determine an available AVHDD, then the selected AVHDD rejects the record command from controller **80**.

Upon receiving the record command, the recording AVHDD then begins recording the stream of data from the source device. If the recording AVHDD runs out of available storage space while the source device is still transmitting the stream of data, the recording AVHDD sends a broadcast message to all AVHDDs within the network requesting that any AVHDD with available storage capacity respond. The recording AVHDD then selects one of the AVHDDs that respond to the broadcast message as the next available AVHDD. Preferably, the next available AVHDD is selected as the AVHDD with the most available storage capacity of those AVHDDs that respond to the broadcast message. The recording AVHDD then forwards the record command to the next available AVHDD. When forwarding the record command to the next available AVHDD, the recording AVHDD first establishes the precise time at which it will run out of available storage space and then forwards that time to the next available AVHDD to indicate at which time the next available AVHDD must begin recording the stream of data. The transfer of recording responsibility is preferably accomplished without the loss of any data. If the controller **80** then sends a subsequent command to the selected AVHDD, the selected AVHDD will forward the command from the controller **80** to the current recording AVHDD.

The control communications between the AVHDDs **32**, **34** and **36** include a real time component and a non-real time component. The non-real time component utilizes AV/C commands and is used to communicate such commands as record and play. This non-real time component is sent using asynchronous transactions over the IEEE 1394-2000 serial bus. The real time communications component is sent over the IEEE 1394-2000 serial bus on an isochronous communications channel and utilizes the isochronous data pipe **66** within the AVHDDs **32**, **34** and **36**. This real time communications component is sent on an isochronous channel which is different than the isochronous channel on which the stream of data is transmitted. The currently recording AVHDD continuously sends information over this isochronous communications channel about itself. When the recording AVHDD determines its available storage capacity is below a predetermined threshold, the next available AVHDD is selected, and a transition time at which the next available AVHDD is to initiate recording is calculated by the recording AVHDD. The recording AVHDD transmits over the isochronous communications channel to the next available AVHDD the transition time and source of the stream of data to be recorded.

Once the next available AVHDD begins recording the stream of data at the designated transition time, it utilizes the non-real time communications component to inform the prior recording AVHDD that it is successfully recording the stream of data. In response to this acknowledgment, the prior recording AVHDD stops transmitting control data on the isochronous communications channel. When the next available AVHDD recognizes that no control data is available on the isochronous communications channel, it begins transmitting control data on the isochronous communications channel as the current recording AVHDD. Alternatively, the real-time communications component is realized using scheduling algorithms, as is well known in the art, which rely on recognizing the transition from one recording AVHDD to the next AVHDD by watching the IEEE 1394-2000 bus time.

In this alternate embodiment, the controller **80** can be implemented as a separate device, as shown in FIG. **4**, or a capable device within the network, such as the settop box **26** or the computer **20**, can serve as the controller and be used to control the operation of the AVHDDs **32**, **34** and **36**, within the network of devices.

In the preferred embodiment of the present invention, the isochronous data pipes **66** within the AVHDDs **32**, **34** and **36** in the network can receive instructions directly from devices within the network and are utilized to initiate and control the operation of the AVHDDs **32**, **34** and **36** during recording of a stream of data. When the user desires to begin recording a stream of data, the user enters a record command from any appropriate interface device within the network, specifying the source device and the particular stream of data to be recorded. The record command is then transmitted to any one of the AVHDDs **32**, **34** and **36** within the network. The AVHDD which receives the record command then locates the source of the data stream to be recorded and instructs this source device to begin transmitting the stream of data on the IEEE 1394-2000 serial bus. The AVHDD also obtains self describing information embedded within the source device over the IEEE 1394-2000 serial bus. The AVHDD utilizes the self describing information to locate the source device and learn how to control the source device. The AVHDD utilizes the AV/C command set appropriate for the source device to control the source device. The stream of data is transmitted in a digital format over an isochronous channel on the IEEE 1394-2000 serial bus.

After receiving an instruction to record an audio/video stream of data, the selected AVHDD then determines the recording AVHDD and forwards the record command to that recording AVHDD. The recording AVHDD then begins recording the stream of data from the source device and will, if necessary, transfer control of recording to the next available AVHDD, as described above.

When a stream of data is being recorded by a current recording AVHDD, the isochronous data pipe **66** within that current recording AVHDD controls the reception of the stream of data from the IEEE 1394-2000 serial bus and the transfer of that stream of data through the read/write channel **72** and onto the media **74**. If the stream of data will exceed the available capacity of the AVHDD, then the AVHDD determines when the media **74** within the AVHDD will be filled, and then utilizes the isochronous data pipe **66** to control the transfer of control to the next available AVHDD. The process of determining the next available AVHDD will be discussed in detail below. When transferring control from one AVHDD to another, the current recording AVHDD contacts the next available AVHDD utilizing the non-real time communications component and the real time communications component, as described above, to inform the next available AVHDD of the transition time when it will need to begin recording the data stream. The next available AVHDD will then begin recording the data stream at the appropriate transition time.

When recording a stream of data, each of the AVHDDs use an internal file system that includes file tables to serve as pointers and connect a stream of data recorded over multiple AVHDDs. The file tables are used during subsequent retrieval and playback of the recorded stream of data. When recording starts at an AVHDD, a file table is generated by the recording AVHDD. The file table is stored on the recording AVHDD and associated with the portion of the stream of data recorded on the recording AVHDD. The file table includes a frame by frame index that correlates each frames' running time within the stream of data to its storage location on the AVHDD. The running time of each frame is measured in hours, minutes, seconds, and frames from the start of the stream of data. For example, the first frame of a stream of data is represented by 0 hours, 0 minutes, 0 seconds, and 1 frame. The file table includes information about each frame of the portion of the recorded stream of data stored on that particular AVHDD, as well as the device from which recording control was transferred, if appropriate, and to which device recording control was transferred, if appropriate. The file tables form a list or map of a data stream recorded over multiple AVHDDs.

A record command is issued by either the controller **80**, the settop box **26**, the television **24**, or the computer **20** and an initial recording AVHDD is selected, as described above. For clarity, the selected AVHDD is referred to as Disk **1**. Disk **1** determines if it has available storage capacity to record all, or a portion of, the stream of data to be recorded. If Disk **1** determines that it has available space, the record command is accepted. If Disk **1** determines that it does not have available space, then Disk **1** determines if another AVHDD has available storage space. If Disk **1** determines that another AVHDD has available storage space, then Disk **1** accepts the record command, makes an appropriate entry in a file table associated with the soon to be recorded stream of data, and forwards the record command to the AVHDD determined to have available storage space. If Disk **1** determines that it does not have available storage space and is unable to locate another AVHDD with available storage space, then the record command is rejected.

In this case, it is determined that Disk **1** has available storage capacity and accepts the record command. When Disk **1** determines that storage space is available, Disk **1** generates and stores a file table associated with the soon to be recorded stream of data. For clarity in describing this example, the soon to be recorded stream of data is herein referred to as AV file A, and the file table associated with AV file A is referred to as file A table. The AV file A and file A table are stored on Disk **1**.

FIG. **5** illustrates an exemplary file A table **100** corresponding to a first portion of the AV file A recorded onto Disk **1**. The file A table **100** is preferably maintained by and recorded onto Disk **1**. Each frame within AV file A is identified by its running time as measured from the start of the AV file A on Disk **1**. If Disk **1** is unable to record the entire AV file A and subsequent AVHDDs are required to complete the recording of AV file A, then the running time of each frame within AV file A, even a frame within a subsequent portion of the AV file A recorded on a subsequent AVHDD, is still measured from the start of the AV file A on Disk **1**. The file A table **100** includes columns **102-108** representing the running time of each frame within AV file A recorded on Disk **1**. Column **102** indicates the running time hours, column **104** indicates the running time minutes, column **106** indicates the running time seconds, and column **108** indicates the running time frames. A column **112** indicates the storage location address of each frame on the Disk **1** and a column **110** indicates the type of address indicated in column **112**. Preferably, each frame within the AV file A recorded on Disk **1** is represented by a row entry on the file A table **100**. Rows **114-120** are examples of four distinct file table entries. Row **114** indicates the first frame of AV file A. The frame of row **114** is measured by its running time relative the AV file A, in this case 0 hours, 0 minutes, 0 seconds, and 1 frame as indicated by columns **102-108**. LBA, or Logical Block Addressing, is a conventional hard disk addressing scheme and indicates that the frame of row **114** is stored at an LBA "0" on the Disk **1**, as indicated in column **112**. Row **116** indicates a randomly selected frame within the first portion of the AV file A recorded on Disk **1**. The frame of row **116** is measured by its running time of 1 hour, 20 minutes, 12 seconds, and 6 frames and is stored at an LBA "12345" within Disk **1**. Row **118** indicates the last frame within the first portion of the AV file A recorded on Disk **1**. This last frame can be either the last frame of the entire AV file A, if the stream of data being recorded is completed, or the last frame of the first portion of the AV file A stored on Disk **1**. The frame of row **118** is measured by its running time of 2 hours, 25 minutes, 15 seconds, and 1 frame and is stored at an LBA "23456" within Disk **1**. The running time of the last frame in row **118** is for illustrative purposes only. The actual running time of a last frame on any AVHDD can be more or less than that indicated in row **118**, the actual running time of any last frame will vary based on the length of an individual AV file or the available storage space of the recording AVHDD.

Row **120** represents the frame immediately following the last frame of AV file A recorded on Disk **1**. Row **120** indicates to the Disk **1** that an additional portion of AV file A is recorded on another AVHDD. Any file table associated with a stream of data that is recorded over multiple AVHDDs includes a row entry similar to that of row **120**, unless the file table is associated with the last portion of the stream of data to be recorded. The last frame of AV file A recorded on Disk **1** is indicated in row **118** with a measured running time of 2 hours, 25 minutes, 15 seconds, and 1 frame and the frame immediately following is indicated in row **120** with a measured running time of 2 hours, 25 minutes, 15 seconds, and 2 frames. The data type of the frame of row **120** is listed in column **110** as "DEVICE". DEVICE indicates to Disk **1** that the frame of row **120** is recorded on an AVHDD other than Disk **1**. The location of this other AVHDD is listed in column **112** of row **120** as "GUID B". GUID B is the device identification of the other AVHDD within the IEEE 1394-2000 serial bus network that resumes recording of the AV file A from where Disk **1** ran out of available storage and stopped recording. For clarity in describing this example, the AVHDD identified by GUID B is herein referred to as Disk **2**.

FIG. **6** illustrates an exemplary file A table **200** corresponding to a second portion of the AV file A recorded onto Disk **2**. Disk **2** resumes recording the stream of data previously being recorded by Disk **1**. The structure of file A table **200** is the same as that of file A table **100** in FIG. **5**. The file A table **200** includes columns **202-208** representing the running time of each frame within the second portion of the AV file A recorded on Disk **2**. Column **202** indicates the running time hours, column **204** indicates the running time minutes, column **206** indicates the running time seconds, and column **208** indicates the running time frames. A column **212** indicates the storage location address of each frame and a column **210** indicates the type of address indicated in column **212**.

Row **214** represents the frame immediately preceding the first frame of the second portion of the AV file A recorded on Disk **2**. Row **214** indicates to Disk **2** that a previous portion of the AV file A is recorded on another AVHDD. Column **210** indicates that the frame of row **214**, with a measured running time of 2 hours, 25 minutes, 15 seconds, and 1 frame, is stored on a device other than Disk **2**. The location of this other device is listed in column **212** as "GUID A". GUID A is the device identification for Disk **1**. The frame identified by columns **202-208** of row **214** matches the frame identified by columns **102-108** of row **118** in FIG. **5**, which is the last frame of the first portion of AV file A recorded on Disk **1**. Row **216** indicates the first frame of the second portion of AV file A recorded on Disk **2**. The frame of row **216** is measured by its running time of 2 hours, 25 minutes, 15 seconds, and 2 frames and is stored at an LBA "123" within Disk **2**. The frame identified by columns **102-108** of row **120** in FIG. **5** matches the frame identified by columns **202-208** of row **216** in FIG. **6**, which is the first frame of the second portion of AV file A recorded on Disk **2**.

In this manner, Disk **1** is able to track the storage location of each frame stored within Disk **1** as well as where a subsequent portion of the stream of data is recorded. Similarly, Disk **2** is able to track the storage location of each frame stored within Disk **2** as well as where a previous portion and a subsequent portion, if appropriate, of the stream of data is recorded. Disk **1** and Disk **2** can store any number of different AV files, depending on storage capacity, where each AV file stored on a particular disk will have an associated file table similar to those illustrated in FIGS. **5** and **6**.

Within the IEEE 1394-2000 serial bus network of the present invention, one of the isochronous channels is allocated as a broadcast channel. Each AVHDD coupled to the IEEE 1394-2000 serial bus continually monitors the broadcast channel for any broadcast messages. As the stream of data is recorded, the recording AVHDD monitors its available storage capacity. When the storage capacity is below a predetermined threshold, the recording AVHDD broadcasts a message over the broadcast channel indicating that it is running out of available storage space. Each AVHDD is programmed to respond to this running-out-of-storage-space message if it has available storage space. The response includes the unique device identification of the responding AVHDD and can include relevant information related to the responding AVHDD, for example the amount of storage capacity available in the responding AVHDD. The recording AVHDD receives responses from all responding AVHDDs and appropriately chooses a next available AVHDD to continue recording the stream of data once the recording AVHDD runs out of storage space. The recording AVHDD can select the next available AVHDD to continue recording based on most available storage space, first to respond, or any other appropriate method of selection.

Using the file tables stored within the internal file system of each AVHDD, a search forward and backward through the recorded stream of data can be accomplished to find a specific location within the recorded stream of data. The file tables are also utilized during retrieval of the recorded stream of data to transfer control of the playback operation to the appropriate AVHDDs on which the stream of data is recorded. During a playback operation, the data is initially retrieved from the desired starting point within the recorded stream of data and transmitted by the appropriate AVHDD to the requesting device over the IEEE 1394-2000 serial bus. When the ending point of the portion of the recorded stream of data on the current AVHDD is reached, the buffer controller **68** within that AVHDD reads the appropriate file table to determine the AVHDD, within the network, on which the next portion of the stream of data is recorded. Once the next AVHDD is identified, the buffer controller **68** performs the non-real time communications and the isochronous data pipe **66** performs the real time communications, as described above, to that next AVHDD, in order to ensure a seamless transition to the next AVHDD. In this same manner, rewind and fast-forward capabilities are also achieved, by following the file tables through the recorded stream of data.

Preferably, the isochronous data pipe **66** in each of the AVHDDs is utilized to control record and retrieval operations, as well as communicate with the other AVHDDs within the automatically configuring storage array of AVHDDs. The preferred embodiment of the isochronous data pipe **66** is taught in U.S. patent application Ser. No. 08/612,322, filed on Mar. 7, 1996 and entitled "ISOCHRONOUS DATA PIPE FOR MANAGING AND MANIPULATING A HIGH-SPEED STREAM OF ISOCHRONOUS DATA FLOWING BETWEEN AN APPLICATION AND A BUS STRUCTURE," which is hereby incorporated by reference. The isochronous data pipe **66** is programmable and will execute a series of instructions on a stream of data in order to perform operations and manipulations on the data as required to place the data in the appropriate format.

In operation, when a user wants a particular stream of data recorded, the user will program an instruction to record a particular stream of data beginning immediately, or at some specified later date. For example, a user could program an instruction to record channel 10 from the settop box **26** between 7:00 PM and 8:00 PM. In the alternate embodiment, a record command is generated and transmitted to the controller **80** corresponding to the programmed instruction. The controller **80** then forwards the record command to one of the AVHDDs **32**, **34** and **36**. In the preferred embodiment, the corresponding record command is transmitted directly to one of the AVHDDs **32**,**34** and **36**. Once the record command is received by one of the AVHDDs **32**, **34** and **36**, that AVHDD then determines if it will accept the record command or determine which one of the other AVHDDs should begin recording the stream of data. The record command is then forwarded, if appropriate, to the recording AVHDD. An instruction is also sent to the settop box **26**, to instruct it that it should transmit channel 10 between 7:00 PM and 8:00 PM over the IEEE 1394-2000 serial bus. An isochronous channel is used to transmit the source stream of data over the IEEE 1394-2000 serial bus from the settop box **26** to the recording AVHDD.

The recording AVHDD begins recording the stream of data from the settop box **26** and a file table is generated by and stored on the recording AVHDD. The file table is associated with the portion of the stream of data recorded on the recording AVHDD. The internal file system of the recording AVHDD also stores the source of the recorded stream of data and associates the source, the recorded stream of data, and the file table. It should be clear that the internal file system can also include additional relevant information pertaining to the recorded stream of data. The file table includes address locations of each frame of the portion of the recorded stream of data stored on the recording AVHDD. The recording AVHDD also begins transmitting control data over the isochronous communications channel concerning itself and the recorded stream of data. If the recording AVHDD does not have enough capacity to record the entire stream of data from the settop box **26**, the recording AVHDD broadcasts a request for any AVHDD within the network to respond if that AVHDD has available storage capacity. From the responding AVHDDs, the recording AVHDD selects a next available AVHDD as the AVHDD that will continue recording the stream of data once the recording AVHDD runs out of storage capacity. The recording AVHDD calculates a transition time at which the next available AVHDD is to start recording and communicates the transition time to the next available AVHDD over the isochronous communications channel. At the designated transition time, the next available AVHDD begins recording the stream of data and also generates a file table with a first entry specifying from which AVHDD control of the recoding was transferred. Subsequent entries into the file table are recorded specifying the storage location of each frame subsequently recorded onto the next available AVHDD.

Once the next available AVHDD begins recording the stream of data, it utilizes the non-real time communications component to inform the prior recording AVHDD that it is successfully recording the stream of data. In response to this acknowledgment, the prior recording AVHDD records an entry in its file table specifying to which AVHDD control of the recording was transferred and stops transmitting control data on the isochronous communications channel. The next available AVHDD recognizes that no control data is available on the isochronous communications channel and begins transmitting control data on the isochronous communications channel as the current recording AVHDD. This process is continued until the entire data stream of the transmission of channel 10 between 7:00 PM and 8:00 PM from the settop box **26** is recorded.

When the user than wants to view the recorded stream of data, a playback command is sent to the controller **80** in the alternate embodiment or to one of the AVHDDs **32**, **34** and **36**, directly, in the preferred embodiment. Once the playback command is received by one of the AVHDDs **32**, **34** and **36**, the beginning of the stream of data is located using the file tables associated with the stream of data which serve as forward and backward pointers. Once the AVHDD on which the beginning of the stream of data is located, that AVHDD then begins transmitting the recorded stream of data over an isochronous channel on the IEEE 1394-2000 serial bus to a specified display device, such as the television **24**. Control is transferred between the AVHDDs, as specified by the file tables, in order to transmit the recorded stream of data. Fast forward and rewind functions, through the recorded stream of data, are also achieved using the file tables stored in each AVHDD that includes portions of the recorded stream of data.

The automatically configuring storage array of the present invention includes a plurality of AVHDDs or other media storage devices on which data can be recorded. The media storage devices communicate with each other in order to store and retrieve streams of data over multiple media storage devices, if necessary. To the user and to the other devices within the network, the automatically configuring storage array appears to be a single media storage device. Accordingly, when a record or playback command is received by any one of the media storage devices, the media storage devices send control communications between themselves to ensure that the stream of data is recorded or transmitted, as appropriate. Control of the record or transmit operation is also transferred between the media storage devices in order to utilize the full capacity of the available media storage devices within the automatically configuring storage array. Preferably, streams of data are also recorded utilizing redundancy techniques in order to prevent the loss of any recorded data. File tables associated with recorded streams of data are utilized to facilitate search and retrieval of the recorded streams of data throughout the media storage devices within the automatically configuring storage array.

Alternative Embodiment

Embedded Object Descriptors

In an alternative embodiment, in a network of devices, including a plurality of media storage devices, the media storage devices operate together to form an automatically configuring storage array for storing and providing streams of data, such as audio and video data. The operation of the automatically configuring storage array of media storage devices is seamless and transparent to the user and to other devices within the network. When a record command is sent to any one of the media storage devices within the automatically configuring storage array, that media storage device will then determine the appropriate media storage device to begin recording the stream of data. The record command is forwarded to that device which will then begin recording the stream of data. When the capacity within the current recording media storage device is filled, the current recording media storage device will determine a next available media storage device and instruct that next available media storage device to begin recording the stream of data. This process continues until the stream of data is recorded and the source device ceases transmitting.

In this alternative embodiment, the stream of data is transmitted from a source device on an isochronous channel over an IEEE 1394-2000 serial bus. Communications between the media storage devices are sent on a separate isochronous communications channel over the IEEE 1394 -2000 serial bus. Also in this alternative embodiment, each of the media storage devices include an isochronous data pipe which controls data storage and retrieval operations, thereby transferring control and communications between the available media storage devices. The media storage devices in this alternative embodiment accept control instructions directly from other devices within the network. In a further alternate embodiment, a separate control device within the network is utilized to provide a control interface between the media storage devices and the other devices within the network. The media storage devices are hard disk drives. Alternatively, any appropriate available media storage device can be utilized within the automatically configuring array of devices.

When recording a stream of data, each of the recording media storage devices use an embedded file system to facilitate subsequent retrieval and playback of the recorded stream of data. Utilizing this embedded file system, when recording starts at a media storage device, an object descriptor is generated. This object descriptor is stored on the media storage device and associated with the stream of data. The object descriptor includes information regarding where an earlier portion of the stream of data is recorded, if appropriate, and where a subsequent portion of the stream of data is recorded, if appropriate. Using these object descriptors, a search forward and backward through the recorded stream of data can be accomplished to find a specific location within the recorded stream of data. The object descriptors are also utilized during retrieval of the recorded stream of data to transfer control of the playback operation to the appropriate media storage devices which were used to record the stream of data.

Within this alternative embodiment, when recording a stream of data from a source device, redundancy techniques are utilized to ensure the integrity of the recorded stream of data. This redundancy is used to prevent the loss of data or facilitate the reconstruction of lost data if one of the media storage devices within the automatically configuring storage array is removed from the network of devices. If a media storage device is removed, then the remaining media storage devices will automatically recreate the data that was stored on the removed media storage device.

Referring to FIGS. **2** and **3**, in this alternative embodiment, each of the AVHDDs **32**, **34** and **36** follow protocols which are described herein and allow each of the AVHDDs **32**, **34** and **36** to coordinate activities with each of the other AVHDDs so that the operation of the AVHDDs appears to a user and other components as a single media storage device. The isochronous data pipe **66** within each of the AVHDDs **32**, **34** and **36** in the network of devices control the storage operations of writing data to and reading data from the AVHDDs **32**, **34** and **36**. As described above, a separate controlling device can also be utilized to monitor and control the activities of the AVHDDs **32**, **34** and **36**. This controller can either be a device within the network, such as the computer **20** or the settop box **26**, or a separate dedicated controller **80**, as illustrated in FIG. **4**.

In the embodiment illustrated in FIG. **4**, the controller **80** is coupled to the AVHDD **36** by the IEEE 1394-2000 cable **82**. The controller **80** includes an appropriate user interface which enables a user to interact with the controller **80** and through the controller **80** control the interconnected components within the automatically configuring storage array. The controller **80** includes the ability to recognize and control the AVHDDs **32**, **34** and **36**, as well as sources of audio/video data such as the video camera **28**, the VCR **30**, the television **24**, the settop box **26** and the computer system **20**.

In the embodiment illustrated in FIG. **4**, when the controller **80** receives an instruction to record an audio/video stream of data, the controller **80** initiates the recording process utilizing the AVHDDs **32**, **34** and **36** available within the network of devices. After receiving an instruction to record an audio/video stream of data, the controller **80** locates the source of the data stream to be recorded, such as the settop box **26**, and instructs it to begin transmitting the stream of data to be recorded on the IEEE 1394-2000 serial bus. The controller **80** obtains self describing information embedded within the source device over the IEEE 1394-2000 serial bus. The controller **80** utilizes the self describing information to locate the source device and learn how to control the source device. The controller **80** then utilizes the AV/C command set, appropriate for the source device, to control the source device. The stream of data is transmitted in a digital format over an isochronous channel on the IEEE 1394-2000 serial bus.

After receiving an instruction to record an audio/video stream of data, the controller **80** also locates one of the AVHDDs **32**, **34** and **36** within the network, and instructs the selected one of the AVHDDs **32**, **34** and **36** to begin recording the stream of data coming from the source device. The controller **80** obtains self describing information embedded within the selected AVHDD over the IEEE 1394-2000 serial bus. The controller **80** utilizes the self describing information to locate the selected AVHDD and learn how to control the selected AVHDD. In this embodiment, it does not matter which one of the AVHDDs **32**, **34** and **36**, the controller **80** selects and instructs to record.

In this alternative embodiment, when the selected AVHDD receives the record instruction from the controller **80**, the selected AVHDD first determines which one of the available AVHDDs within the network should record the next stream of data. This determination is based on the available capacity of each of the available AVHDDs and the current responsibilities of those AVHDDs. Once the selected AVHDD determines which one of the available AVHDDs will record this stream of data, the selected AVHDD forwards the record command to that available AVHDD, which will be referred to herein as the recording AVHDD. The recording AVHDD then begins recording the stream of data from the source device. If the recording AVHDD runs out of available storage space while the source device is still transmitting the stream of data, the recording AVHDD, will locate the next available AVHDD within the network and forward the record command to that AVHDD. When forwarding the record command to the next available AVHDD, the recording AVHDD first establishes the precise time at which it will run out of available storage space and at which time the next available AVHDD must begin recording the stream of data. The transfer of recording responsibility is preferably accomplished without the loss of any data. If the controller **80** then sends a subsequent command to the selected AVHDD, the selected AVHDD will forward the command from the controller **80** to the current recording AVHDD.

The control communications between the AVHDDs **32**, **34** and **36** include a real time component and a non-real time component. The non-real time component utilizes AV/C commands and is used to communicate such commands as record and play. This non-real time component is sent using asynchronous transactions over the IEEE 1394-2000 serial bus. The real time communications component is sent over the IEEE 1394-2000 serial bus on an isochronous communications channel and utilizes the isochronous data pipe **66** within the AVHDDs **32**, **34** and **36**. This real time communications component is sent on an isochronous channel which is different than the isochronous channel on which the stream of data is transmitted. The currently recording AVHDD continuously sends information over this isochronous communications channel about itself. One isochronous cycle before the time of the transition from the currently recording AVHDD to the next available AVHDD, the currently recording AVHDD changes the information transmitted on the isochronous communications channel to provide that the next available AVHDD is the current recording AVHDD. In response, the next available AVHDD then begins recording the stream of data on the next isochronous cycle.

Once the next available AVHDD begins recording the stream of data, it utilizes the non-real time communications component to inform the prior recording AVHDD that it is successfully recording the stream of data. In response to this acknowledgment, the prior recording AVHDD stops transmitting control data on the isochronous communications channel. When the next available AVHDD recognizes that no control data is available on the isochronous communications channel, it begins transmitting control data on the isochronous communications channel as the current recording AVHDD. Alternatively, the real-time communications component is realized using scheduling algorithms, as is well known in the art, which rely on recognizing the transition from one recording AVHDD to the next AVHDD by watching the IEEE 1394-2000 bus time.

In this alternate embodiment, the controller **80** can be implemented as a separate device, as shown in FIG. **4**, or a capable device within the network, such as the settop box **26** or the computer **20**, can serve as the controller and be used to control the operation of the AVHDDs **32**, **34** and **36**, within the network of devices.

In this embodiment of the present invention, the isochronous data pipes **66** within the AVHDDs **32**, **34** and **36** in the network can receive instructions directly from devices within the network and are utilized to initiate and control the operation of the AVHDDs **32**, **34** and **36** during recording of a stream of data. When the user desires to begin recording a stream of data, the user enters a record command from any appropriate interface device within the network, specifying the source device and the particular stream of data to be recorded. The record command is then transmitted to any one of the AVHDDs **32**, **34** and **36** within the network. The AVHDD which receives the record command then locates the source of the data stream to be recorded and instructs this source device to begin transmitting the stream of data on the IEEE 1394-2000 serial bus. The AVHDD also obtains self describing information embedded within the source device over the IEEE 1394-2000 serial bus. The AVHDD utilizes the self describing information to locate the source device and learn how to control the source device. The AVHDD utilizes the AV/C command set appropriate for the source device to control the source device. The stream of data is transmitted in a digital format over an isochronous channel on the IEEE 1394-2000 serial bus.

After receiving an instruction to record an audio/video stream of data, the receiving AVHDD then determines the next available AVHDD and forwards the record command to that next available AVHDD. The next available AVHDD then begins recording the stream of data from the source device and will, if necessary, transfer control of recording to the next available AVHDD, as described above.

Within the alternate embodiment, when a stream of data is being recorded by a current recording AVHDD, the isochronous data pipe **66** within that current recording AVHDD controls the reception of the stream of data from the IEEE 1394-2000 serial bus and the transfer of that stream of data through the read/write channel **72** and onto the media **74**. If the stream of data will exceed the available capacity of the AVHDD, then the AVHDD determines when the media **74** within the AVHDD will be filled, and then utilizes the isochronous data pipe **66** to control the transfer of control to the next available AVHDD. When transferring control from one AVHDD to another, the current AVHDD contacts the next available AVHDD utilizing the non-real time communications component and the real time communications component, as described above, to inform the next available AVHDD when it will need to begin recording the data stream. The next available AVHDD will then begin recording the data stream at the appropriate time.

In this alternative embodiment, when recording a stream of data, each of the AVHDDs use an embedded file system and object descriptors to serve as pointers and connect a stream of data recorded over multiple AVHDDs. The embedded file system and object descriptors are used during subsequent retrieval and playback of the recorded stream of data. When recording starts at an AVHDD, an object descriptor is generated by the recording AVHDD. The object descriptor is stored on the media storage device and associated with the stream of data. The object descriptor includes information about the recorded stream of data, including the device from which recording control was transferred, if appropriate, and to which device recording control was transferred, if appropriate. The object descriptors form a list or map of a data stream recorded over multiple AVHDDs.

Using the object descriptors stored with the data, a search forward and backward through the recorded stream of data can be accomplished to find a specific location within the recorded stream of data. The object descriptors are also utilized during retrieval of the recorded stream of data to transfer control of the playback operation to the appropriate AVHDDs on which the stream of data is recorded. During a playback operation, the data is initially retrieved from the desired starting point within the recorded stream of data and transmitted by the appropriate AVHDD to the requesting device over the IEEE 1394-2000 serial bus. When the ending point of the recorded stream of data on the current AVHDD is reached, the buffer controller **68** within that AVHDD reads the appropriate object descriptor to determine the AVHDD, within the network, on which the next portion of the stream of data is recorded. Once the next AVHDD is identified, the buffer controller **68** performs the non-real time communications and the isochronous data pipe **66** performs the real time communications, as described above, to that next AVHDD, in order to ensure a seamless transition to the next AVHDD. In this same manner, rewind and fast-forward capabilities are also achieved, by following the object descriptors through the recorded stream of data.

The isochronous data pipe **66** in each of the AVHDDs is utilized to control record and retrieval operations, as well as communicate with the other AVHDDs within the automatically configuring storage array of AVHDDs. The isochronous data pipe **66** is programmable and will execute a series of instructions on a stream of data in order to perform operations and manipulations on the data as required to place the data in the appropriate format.

In the operation of this alternative embodiment, when a user wants a particular stream of data recorded, the user will program an instruction to record a particular stream of data beginning immediately, or at some specified later date. For example, a user could program an instruction to record channel 10 from the settop box **26** between 7:00 PM and 8:00 PM. In the embodiment illustrated in FIG. **4**, a record command is generated and transmitted to the controller **80** corresponding to the programmed instruction. The controller **80** then forwards the record command to one of the AVHDDs **32**, **34** and **36**. In the embodiment illustrated in FIG. **2**, the corresponding record command is transmitted directly to one of the AVHDDs **32**, **34** and **36**. Once the record command is received by one of the AVHDDs **32**, **34** and **36**, that AVHDD then determines which one of the available AVHDDs **32**, **34** and **36** should begin recording the stream of data. The record command is then forwarded, if appropriate, to the recording AVHDD. An instruction is also sent to the settop box **26**, to instruct it that it should transmit channel 10 between 7:00 PM and 8:00 PM over the IEEE 1394-2000 serial bus. An isochronous channel is used to transmit the source stream of data over the IEEE 1394-2000 serial bus from the settop box **26** to the recording AVHDD.

The recording AVHDD begins recording the stream of data from the settop box **26**. At the beginning of the recorded stream of data, an object descriptor is recorded specifying that this is the beginning of the recorded stream of data and from where the recorded stream of data is received. The recording AVHDD also begins transmitting control data over the isochronous communications channel concerning itself and the recorded stream of data. If the recording AVHDD does not have enough capacity to record the entire stream of data from the settop box **26**, then one isochronous cycle before the necessary time of transition, the currently recording AVHDD changes the information transmitted on the isochronous communications channel to provide that the next available AVHDD is the current recording AVHDD. In response to this communications information, the next available AVHDD begins recording the stream of data on the next isochronous cycle. At the beginning of this recorded portion of the stream of data, the next available AVHDD records an object descriptor specifying the source of the stream of data and from which AVHDD control of the recording was transferred.

Once the next available AVHDD begins recording the stream of data, it utilizes the non-real time communications component to inform the prior recording AVHDD that it is successfully recording the stream of data. In response to this acknowledgment, the prior recording AVHDD stops transmitting control data on the isochronous communications channel. The next available AVHDD recognizes that no control data is available on the isochronous communications channel and begins transmitting control data on the isochronous communications channel as the current recording AVHDD. This process is continued until the entire data stream of the transmission of channel 10 between 7:00 PM and 8:00 PM from the settop box **26** is recorded.

When the user than wants to view the recorded stream of data, a playback command is sent to the controller **80** in the embodiment illustrated in FIG. **4** or to one of the AVHDDs **32**, **34** and **36**, directly, in the embodiment illustrated in FIG. **2**. Once the retrieval command is received by one of the AVHDDs **32**, **34** and **36**, the beginning of the stream of data is located using the object descriptors stored with the stream of data which serve as forward-and backward pointers. Once the AVHDD on which the beginning of the stream of data is located, that AVHDD then begins transmitting the recorded stream of data over an isochronous channel on the IEEE 1394-2000 serial bus to a specified display device, such as the television **24**. Control is transferred between the AVHDDs, as specified by the object descriptors, in order to transmit the recorded stream of data. Fast forward and rewind functions, through the recorded stream of data, are also achieved using the object descriptors stored within the recorded stream of data.

The automatically configuring storage array of the alternate embodiment of the present invention includes a plurality of AVHDDs or other media storage devices on which data can be recorded. The media storage devices communicate with each other in order to store and retrieve streams of data over multiple media storage devices, if necessary. To the user and to the other devices within the network, the automatically configuring storage array appears to be a single media storage device. Accordingly, when a record or playback command is received by any one of the media storage devices, the media storage devices send control communications between themselves to ensure that the stream of data is recorded or transmitted, as appropriate. Control of the record or transmit operation is also transferred between the media storage devices in order to utilize the full capacity of the available media storage devices within the automatically configuring storage array. Streams of data are also recorded utilizing redundancy techniques in order to prevent the loss of any recorded data. Object descriptors are also stored with recorded streams of data in order to facilitate search and retrieval of the recorded streams of data throughout the media storage devices within the automatically configuring storage array.

Redundancy

In the preferred embodiment of the present invention, when a stream of data is recorded within the automatically configuring storage array, the stream of data is recorded using a level of redundancy in order to ensure the integrity of the recorded data and prevent any loss of data. This redundancy is used to prevent the loss of data and facilitate the reconstruction of lost data when one of the AVHDDs within the automatically configuring storage array of the present invention is removed from the network of devices or otherwise becomes unavailable. Using a redundancy technique, if a media storage device is removed, then the remaining AVHDDs will preferably automatically recreate and record the data that was stored on the removed AVHDD.

Any available redundancy techniques can be used to store a stream of data within the automatically configuring storage array of the present invention. In such redundancy techniques, data or relationships among data, are stored in multiple locations. In one such technique, data is mirrored or duplicated and stored in two separate areas of the storage array. Using a mirror technique, two separate copies of the data are stored in different locations within the automatically configuring storage array. This method has the disadvantage of requiring more storage capacity within the array, but there is a high probability of recreating any lost data.

Using a parity redundant technique, a portion of the memory storage array is dedicated to storing redundant data. The size of this redundant portion is less than the remaining space within the array used to store the actual data. In an array including five AVHDDs, one of the AVHDDs could be dedicated as the parity AVHDD. This method requires less capacity than the mirror technique, but also has a lower probability of recreating any lost data.

Preferably, some level of redundancy techniques are used to record data within the automatically configuring storage array of the present invention. Such techniques are generally referred to as redundant array of independent disks (RAID) techniques. The term RAID means a disk array in which part of the physical storage capacity is used to store redundant information about data stored on the remainder of the storage capacity. This redundant information enables regeneration of user data in the event that one of the AVHDDs within the array is removed or fails. A detailed discussion of RAID systems is found in a book entitled "The RAIDBook: Sixth Edition," published by the RAID Advisory Board, North Grafton, Mass.

The present invention has been described in terms of specific embodiments incorporating details to facilitate the understanding of principles of construction and operation of the invention. Such reference herein to specific embodiments and details thereof is not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications may be made in the embodiment chosen for illustration without departing from the spirit and scope of the invention. Specifically, it will be apparent to those skilled in the art that while the preferred embodiment of the present invention is used with an IEEE 1394-2000 serial bus structure, the present invention could also be implemented on any other appropriate bus structures. Additionally, it will also be apparent that while the preferred embodiment of the present invention includes AVHDDs within the automatically configuring storage array, any other appropriate media storage device can also be used.

What is claimed is:

1. A method of recording data within an automatically configuring storage array including a plurality of media storage devices comprising:

a. receiving a record command to record a stream of data within the array;

b. recording the stream of data on media within one or more media storage devices within the array, thereby forming a recorded stream of data; and

c. recording a file table associated with the recorded stream of data, wherein the file table includes identifying and pointing information about the recorded stream of data.

2. The method as claimed in claim **1** wherein control communications are sent to identify a next available media storage device when recording responsibility is transferred from a current recording media storage device to the next available media storage device.

3. The method as claimed in claim **1** wherein control communications and the stream of data are sent over a serial bus that substantially complies with an IEEE 1394 standard.

4. The method as claimed in claim **1** wherein each media storage device that stores a portion of the recorded stream of data includes the file table associated with the portion of the recorded stream of data stored on that media storage device.

5. The method as claimed in claim **4** wherein the identifying and pointing information within the file table includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data.

6. The method as claimed in claim **1** wherein the record command is received from a remote controller.

7. The method as claimed in claim **1** wherein the stream of data is transmitted on a data isochronous channel.

8. The method as claimed in claim **1** further comprising recording redundant information regarding the stream of data which is used to reconstruct lost data within the recorded stream of data.

9. The method as claimed in claim **1** wherein each frame within the recorded stream of data is identified by the elapsed time from the start of the recorded stream of data to the frame, wherein the elapsed time is measured in hours, minutes, seconds and frames.

10. A method of recording data within an automatically configuring storage array including a plurality of media storage devices comprising:

a. receiving a record command to record a stream of data within the array;

b. recording the stream of data on media within one or more media storage devices within the array, thereby forming a recorded stream of data; and

c. recording a file table associated with the recorded stream of data, wherein the file table includes identifying and pointing information about the recorded stream of data;

wherein each media storage device that stores a portion of the recorded stream of data includes the file table associated with the portion of the recorded stream of data stored on that media storage device.

11. The method as claimed in claim **10** wherein control communications are sent to identify the next available media storage device when recording responsibility is transferred from a current recording media storage device to the next available media storage device.

12. The method as claimed in claim **10** wherein the control communications and the stream of data are sent over a serial bus that substantially complies with an IEEE 1394 standard.

13. The method as claimed in claim **10** wherein the identifying and pointing information within the file table includes a correlation between each frame within the portion of the recorded stream of data and that frames' storage location within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data.

14. A storage array within a network of devices including data source devices and data reception devices, the automatically configuring storage array including a plurality of media storage devices having ability to record a received stream of data, thereby forming a recorded stream of data, wherein each media storage device that stores a portion of the recorded stream of data includes a file table associated with the portion of the recorded stream of data for identifying and pointing to portions of the recorded stream of data stored on different media storage devices.

15. The automatically configuring storage array as claimed in claim **14** wherein the file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data.

16. The automatically configuring storage array as claimed in claim **14** wherein the recorded stream of data is recorded utilizing redundancy recording techniques.

17. The automatically configuring storage array as claimed in claim **14** further comprising a controller coupled to the media storage devices to initiate record and transmit operations.

18. The automatically configuring storage array as claimed in claim **14** wherein the media storage devices include one or more hard disk drives.

19. The automatically configuring storage array as claimed in claim **14** wherein the automatically configuring storage array is formed within a serial bus network of devices that substantially complies with an IEEE 1394 standard.

20. A network of devices comprising:

a. a source device for providing a stream of data; and

b. a storage array coupled to the source device, the storage array including a plurality of media storage devices having ability to record the received stream of data, thereby forming a recorded stream of data, wherein each media storage device that stores a portion of the recorded stream of data includes a file table associated with the portion of the recorded stream of data for identifying and pointing to portions of the recorded stream of data stored on different media storage devices.

21. The network of devices as claimed in claim **20** wherein the file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data.

22. The network of devices as claimed in claim **20** wherein the recorded stream of data is recorded utilizing redundancy recording techniques.

23. The network of devices as claimed in claim **20** further comprising a controller coupled to the media storage devices to initiate record and transmit operations.

24. The network of devices as claimed in claim **20** wherein the media storage devices include one or more hard disk drives.

25. The network of devices as claimed in claim **20** wherein the network of devices is formed by a serial bus network of devices that substantially complies with an IEEE 1394 standard.

26. A distributed file table representing storage locations corresponding to a recorded stream of data, the distributed file table including one or more file tables, wherein each file table is associated with a portion of the recorded stream of data stored on one of a plurality of media storage devices within a network of devices and includes identifying information about the portion of the recorded stream of data on the media storage device and pointing information about other portions of the recorded stream of data on different media storage devices, further wherein each file table is maintained by and recorded onto the media storage device on which the associated portion of the recorded stream of data is recorded.

27. The distributed file table as claimed in claim **26** wherein the file table associated with the portion of the recorded stream of data includes a correlation between each frame within the portion of the recorded stream of data and a storage location of the frame within the media storage device, a location of a previously recorded portion of the recorded stream of data, and a location of a subsequently recorded portion of the recorded stream of data.

28. The distributed file table as claimed in claim **26** further comprising a controller coupled to the media storage device to maintain and record the information included within the file table corresponding to the media storage device.

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